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(71) Applicant: The Boeing Company
Seal Beach, California 90740-1515 (US)

(72) Inventors:

- Lak, Tibor I.
Huntington Beach, CA 92647 (US)
- Rogers, Gene
San Pedro, CA 90732 (US)

• Weber, James F.
Moorpark, CA 93021 (US)

• Merlin, Michael V.

Anaheim, CA 92807 (US)

• Gaynor, Timothy L., III

Cypress, CA 90630 (US)

• Davis, John E.

Claremont, CA 91711 (US)

• Gerhardt, David L.

Redondo Beach, CA 90277 (US)

(74) Representative:

Land, Addick Adrianus Gosling et al
Arnold & Sledsma,

Advocaten en Octroolgemaachtigden,

Sweelinckplein 1

2517 GK Den Haag (NL)

(54) Cryogenic liquid heat exchanger system with fluid ejector

(57) A cryogenic liquid heat exchanger system (10) has a subatmospheric pressure reservoir (14), a tube (24), and an initial fluid ejector (12). The sub-atmospheric pressure reservoir (14) has a vacuum exhaust (32). The tube (24) extends through the reservoir (14). The initial fluid ejector (12) has a suction chamber inlet that is functionally connected to the reservoir vacuum exhaust (32). The system may have a plurality of fluid ejectors connected to one or more exhausts either in series or parallel. The initial fluid ejector (12) may receive one or more pressurized fluid streams (36), and the streams may be steam. A process for generating sub-atmospheric pressures in a cryogenic fluid heat exchanger reservoir (14) includes the step of discharging an initial fluid stream (36) into an initial fluid ejector (12) having a suction chamber (30) functionally connected to an exhaust (32) of the reservoir (14). A process for generating sub-atmospheric pressures in a cryogenic fluid heat exchanger reservoir includes the step of using a fluid ejector (12) to reduce the pressure in the reservoir (14). In either process, cooling cryogenic fluid (16) is directed through the reservoir (14). The cooling cryogenic fluid (16) may be liquid nitrogen or liquid hydrogen. In either process, an incoming cryogenic fluid stream (22) is directed through a tube (24) that extends through the reservoir (14). The incoming cryogenic fluid (22) may be liquid oxygen or liquid hydrogen, or any other suitable

cryogenic fluid.

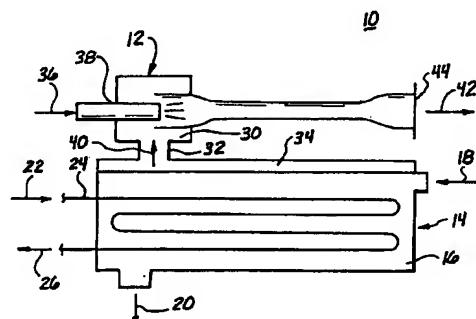


Fig. 1

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Description**BACKGROUND OF THE INVENTION****1. Field of the Invention**

[0001] This invention relates to cooling systems and, more specifically, to cryogenic cooling systems.

2. Description of the Related Art

[0002] Propulsion systems utilizing cryogenic liquid oxygen and/or hydrogen, such as the Space Shuttle, Atlas/Centaur, Delta, etc., are currently filled from the facility storage tanks and subsequently allowed to cool in the flight tanks in order to reject the heat absorbed by the liquid as a result of environmental heat leak, transfer line, and tank wall chill-down. The cooling of the liquid bulk is desirable in order to increase the liquid density so that more impulse mass can be stored in the tank, and also to reduce the liquid vapor pressure so that the tank operating pressure and tank weight is minimized.

[0003] The prior art discloses numerous process and systems for cooling the cryogenic liquid. The cryogenic liquid may be cooled through jackets on the tanks. However, due to weight restrictions and the problems associated with such low temperature cooling, a cryogenic liquid stream is cooled. The cryogenic liquid stream that initially charges the tank may be cooled prior to entering the tank. The cryogenic liquid in the tank is furthered cooled through reducing the temperature of a recirculation stream of cryogenic fluid.

[0004] The prior art discloses a cryogenic heat exchanger system that comprises a tube or tubes that extend through a reservoir. The cryogenic stream that is to be cooled is directed through the tubes. The reservoir is filled with another cryogenic fluid at a lower temperature. The tubes through which the cryogenic fluid stream flows are submerged in the reservoir, resulting in the cryogenic fluid stream being cooled as it moves through the tubes.

[0005] The cryogenic fluid in the heat exchanger reservoir may be at a sub-atmospheric pressure to maintain it at a lower temperature and assist in thermal transfer between it and the cryogenic fluid stream. The prior art discloses using a dedicated compressor to create the sub-atmospheric pressure and compress the vapor from the reservoir prior to discharge. This process and system directly requires the use of the compressor, which is a complex piece of equipment.

[0006] Therefore, a need exists to create a sub-atmospheric pressure in the heat exchanger reservoir system that requires simpler dedicated equipment than a compressor.

SUMMARY OF THE INVENTION

[0007] In an aspect of the invention, a cryogenic liquid

heat exchanger system comprises a subatmospheric pressure reservoir, a tube, and an initial fluid ejector. The sub-atmospheric pressure reservoir has a vacuum exhaust. The tube extends through the reservoir. The initial fluid ejector has a suction chamber inlet that is functionally connected to the reservoir vacuum exhaust.

[0008] In further aspects of the invention, suction chamber inlets of a plurality of fluid ejectors are functionally connected to the reservoir vacuum exhaust or to a plurality of reservoir exhausts. The plurality of fluid ejectors may be functionally connected to the exhausts in series or in parallel. The initial fluid ejector may have one or more fluid stream inlet nozzles. The initial fluid ejector may be a steam ejector.

[0009] In an aspect of the invention, a process for generating sub-atmospheric pressures in a cryogenic fluid heat exchanger reservoir comprises the step of discharging an initial fluid stream into an initial fluid ejector having a suction chamber functionally connected to an exhaust of the reservoir. A further aspect of the invention may have a plurality of initial fluid streams discharging into the initial fluid ejector. Another aspect of the invention has a plurality of initial fluid streams discharging to a plurality of initial fluid ejectors having suction chambers, wherein the suction chambers are functionally connected to a plurality of reservoir exhausts. In another aspect of the invention, a plurality of fluid streams are discharged into one or more serially connected fluid ejectors, wherein a first fluid ejector of the serially connected fluid ejectors has a suction chamber that is functionally connected to an outlet of the initial fluid ejector. The fluid stream may be steam.

[0010] In a further aspect of the invention, cooling cryogenic fluid may be directed through the reservoir. In another aspect of the invention, the cooling cryogenic fluid comprises liquid nitrogen, liquid hydrogen or any other cryogenic liquid with suitable properties.

[0011] In a further aspect of the invention, an incoming cryogenic fluid stream is directed through a tube that extends through the reservoir. In another aspect of the invention, the incoming cryogenic fluid comprises liquid oxygen or liquid hydrogen.

[0012] In an aspect of the invention, a process for generating sub-atmospheric pressures in a cryogenic fluid heat exchanger reservoir comprises the step of using a fluid ejector to reduce the pressure in the reservoir. Further aspects of this aspect of the invention were discussed above in connection with the process for generating sub-atmospheric pressures in a cryogenic fluid heat exchanger reservoir.

BRIEF DESCRIPTION OF THE DRAWING

[0013] Figure 1 schematically shows a cryogenic liquid heat exchanger system according to an embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] Referring now to Figure 1, wherein like reference numerals refer to like elements throughout the figures, a cryogenic liquid heat exchanger system 10 uses a fluid ejector 12 to create a sub-atmospheric pressure in the system's reservoir tank 14. The fluid ejector 12 has no moving parts, therefore the system 10 is simpler than the cryogenic liquid heat exchangers of the prior art that use a dedicated mechanical system to create the sub-atmospheric pressure. The fluid ejector 12 does use a pressurized fluid stream 36 which may be generated by a mechanical system with moving parts, such as a compressor, a pump, or a boiler.

[0015] The reservoir 14 is a tank that holds a cooling cryogenic fluid 16. The cryogenic fluid 16 is shown entering the reservoir 14 on the right as a reservoir inlet stream 18. The cryogenic fluid 16 is shown exiting the reservoir 14 from the bottom as a reservoir outlet stream 20.

[0016] The cryogenic liquid heat exchanger system 10 cools a cryogenic fluid stream 22. The stream 22 flows through a tube 24 that extends through the reservoir 14. The tube 24 is submerged in the cooling cryogenic fluid 16 in the reservoir 14. The cooling cryogenic fluid 16 is colder than the stream 22. The stream 22 exits the tube 24 and the reservoir 14 as a cooler cryogenic liquid stream 26. Embodiments of the invention comprise many arrangements of the reservoir 14 and the tube 24, as is known by those skilled in the art.

[0017] The reservoir 14 is kept at a sub-atmospheric pressure through the use of the fluid ejector 12. The fluid ejector 12 comprises a suction chamber 30 that is functionally connected to a vacuum vent 32 in the reservoir. The vent 32 is located at the top of the reservoir 12 such that it has access to ullage 34 in the reservoir.

[0018] To use the fluid ejector 12 to generate the sub-atmospheric pressure, the pressurized fluid stream 36 is directed into a fluid stream inlet nozzle 38 of the ejector 12. As the stream 36 flows through the fluid ejector 12, vapor 40 is drawn up from the ullage 34, through the vacuum vent 32 and into the ejector suction chamber 30, resulting in sub-atmospheric pressure created in the reservoir 14. The vapor 40 mixes with the high pressure fluid stream 36 to form an ejector discharge stream 42 that exits the ejector through a discharge end 44 of the fluid ejector 12. The discharge end 44 is distally located from the fluid stream inlet nozzle 38.

[0019] Embodiments of the invention may have many different variations on the use of fluid ejectors. A fluid ejector may use any suitable pressurized fluid stream to operate, the fluid being a gas or a liquid. The fluid ejector 12 and the pressurized fluid flow 36 are designed to prevent localized freezing in the ejector. In an embodiment of the invention, a steam flow is the pressurized fluid stream. In an embodiment of the invention, a fluid ejector may have multiple inlet nozzles. In an embodiment

of the invention, the suction chambers of multiple fluid ejectors may be functionally connected to one or more reservoir vents. In an embodiment of the invention, a plurality of fluid ejectors may be functionally connected

5 either serially or in parallel. Other embodiments of the invention may have other fluid ejector arrangements, such as those skilled in the art are able to design that result in the desired and predetermined sub-atmospheric pressure in the reservoir 14.

[0020] In a preferred embodiment of the invention, the sub-atmospheric pressure in the reservoir is less than 10 1.5 psia. Embodiments of the invention use any suitable combination of cryogenic fluids as the cooling cryogenic fluid 16 and the cryogenic fluid stream 22. Examples of

15 the cooling cryogenic fluids include liquid nitrogen or liquid hydrogen. Examples of cryogenic fluid streams include liquid oxygen and liquid hydrogen. In a further embodiment of the invention, the cryogenic liquid heat exchanger system 10 cools the liquid oxygen or the liquid hydrogen of the incoming cryogenic fluid stream 22 to less than 120°F and 26°F, respectively.

[0021] Although presently preferred embodiments of the present invention have been described in detail hereinabove, it should be clearly understood that many 25 variations and/or modifications of the basic inventive concepts herein taught, which may appear to those skilled in the pertinent art, will still fall within the spirit and scope of the present invention, as defined in the appended claims.

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Claims

1. A cryogenic liquid heat exchanger system comprising
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 - (a) a sub-atmospheric pressure reservoir comprising a vacuum exhaust
 - (b) a tube that extends through the reservoir; and
 - (c) an initial fluid ejector having a suction chamber inlet that is functionally connected to the reservoir vacuum exhaust.
- 45 2. The system of claim 1, wherein suction chamber inlets of a plurality of fluid ejectors are functionally connected to the reservoir vacuum exhaust.
3. The system of claim 1, comprising a plurality of reservoir vacuum exhausts.
4. The system of claim 3, wherein suction chamber inlets of a plurality of fluid ejectors are functionally connected to the plurality of reservoir vacuum exhausts.
- 55 5. The system of claim 3, wherein suction chamber inlets of a plurality of fluid ejectors are functionally connected to one or more reservoir vents.

- the plurality of reservoir vacuum exhaust, respectively.
6. The system of claim 1, further comprising one or more additional fluid ejectors functionally and serially connected to a discharge of the initial fluid ejector.
7. The system of claim 1, wherein the initial fluid ejector has one or more stream inlet nozzles.
8. The system of claim 1, wherein the initial ejector is a steam ejector.
9. A process for generating sub-atmospheric pressures in a cryogenic fluid heat exchanger reservoir comprising the step of discharging an initial fluid stream into an initial fluid ejector having a suction chamber functionally connected to an exhaust of the reservoir.
10. The process of claim 9, wherein the discharging step further comprises the step of discharging a plurality of initial fluid streams into the initial fluid ejector.
11. The process of claim 9, wherein the discharging step further comprises discharging a plurality of initial fluid streams into a plurality of initial fluid ejectors having a suction chamber, wherein the suction chambers are functionally connected to a plurality of reservoir exhausts.
12. The process of claim 9, further comprising the step of discharging a plurality of fluid streams into one or more serially connected fluid ejectors, wherein a first fluid ejector of the serially connected fluid ejectors has a suction chamber that is functionally connected to an outlet of the initial fluid ejector.
13. The process of claim 9, wherein the fluid stream is a steam flow.
14. A process for generating sub-atmospheric pressures in a cryogenic fluid heat exchanger reservoir comprising the step of using one or more fluid ejectors to reduce the pressure in reservoir.
15. The process of claim 14, further comprising the step of using serially connected fluid ejectors to reduce the pressure in the reservoir.
16. The process of claim 14 or 15, wherein the using step further comprises the step of directing a steam flow into the fluid ejector.
17. The process of any of claims 9-16, further comprising the step of directing cooling cryogenic fluid through the reservoir.
- 5
18. The process of claim 17, wherein the cooling cryogenic fluid comprises liquid nitrogen or liquid hydrogen.
- 10
19. The process of any of claims 9-18, further comprising the step of directing an incoming cryogenic fluid stream through a tube that extends through the reservoir.
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20. The process of claim 17, 18 or 19, wherein the incoming cryogenic fluid comprises liquid oxygen or liquid hydrogen.
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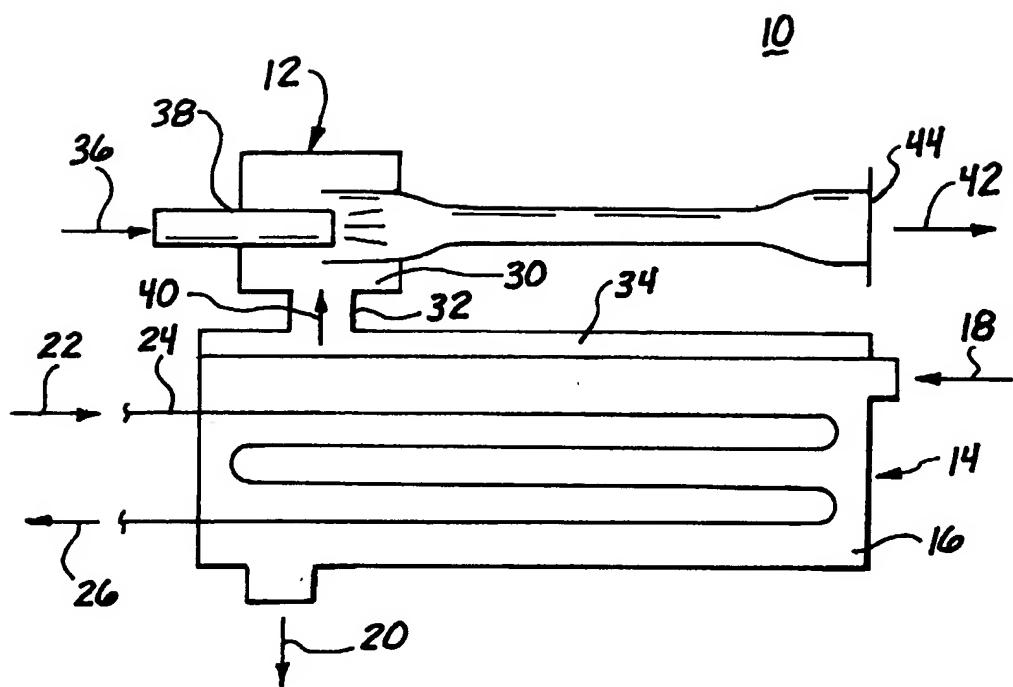


Fig. 1



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(71) Applicant: The Boeing Company
Seal Beach, California 90740-1515 (US)

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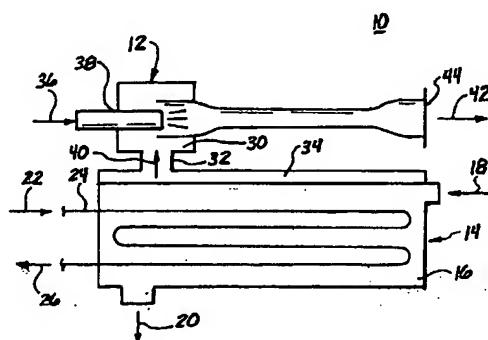
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2517 GK Den Haag (NL)

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EUROPEAN SEARCH REPORT

Application Number
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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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Y	US 5 647 221 A (GARRIS JR CHARLES A) 15 July 1997 (1997-07-15) * abstract; figure 5 * * column 2, paragraph 2 * * column 2, line 43 - line 47 * * column 13, paragraph 2 * ---	1,9,14, 17-20	
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The present search report has been drawn up for all claims			
Place of search	Date of completion of the search	Examiner	
THE HAGUE	28 November 2000	Yousufi, S	
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
 The members are as contained in the European Patent Office EDP file on
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